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NASA TECHNICAL MEMORANDUM

NASA TM-88522

9P.

PROPERTY OF RADIALLY QUADRATIC REFLECTOR SYSTEMS

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Translation of: Japanese Electronics and Communications Society Journal, Vol. 53, No. 1, November 1970, pp. 707-708

(NASA-TM-88522) PROPERTY OF RADIALLY QUADRATIC REFLECTOR SYSTEMS (National Aeronautics and Space Administration) 9 p

N87-18689

CSCL 20N

Unclas

G3/32 43371

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 SEPTEMBER 1986

A PROPERTY OF RADIALLY QUADRATIC REFLECTOR SYSTEMS

M. Mizusawa and T. Katagi
(Mitsubishi Electric Co., Inc., Kamakura Factory, Kamakura, Japan 247)

Translation of "Kaiten nijikyokumen kagami kei no 1 seishitsu", Denshi Tsūshin Gakkai Ronbunshi (Japanese Electronics and Communications Society Journal), Vol. 53-B, No. 11, Nov. 1970, pp. 707-708.

JET PROPULSION LABORATORIES
PASADENA, CA 91109 MAY 1986

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M. Mizusawa and T. Katagi
(Mitsubishi Electric Co., Inc., Kamakura Factory, Kamakura, Japan 247)

Radially parabolic reflectors and radially hyperbolic /707* reflectors are widely used as reflector mirrors for Cassegrain and parabolic antennas. Until now, these have mostly been radially symmetrical, but recently, Cassegrain antennas placed into an off-set system [1] or Cassegrain antennas which utilize conical horn-reflectors as their primary radiator have been considered as means for preventing blocking by utilizing secondary reflectors. Large-scale mobile antennas which utilize systems comprised of several reflectors as their primary radiator system [2], as shown in Figure 1, have also been considered in order to be able to establish receivers on the ground. It is difficult to strictly calculate the radiation properties of these types of complex antennas, but this article will show that, when considered optical-geometrically, these types of antennas all possess similar values to common conical horn-reflector antennas [3] which are composed of a horn

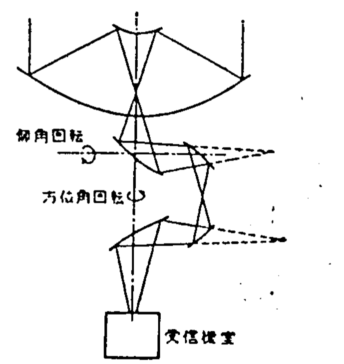


図1 4枚の鏡面を一次放射器系にもつカセグレンアンテナ
Fig. 1—Cassegrain antenna with the primary radiator composed of 4 mirrors.

key
- a elevation rotation
- b declination rotation
- c receiver room

* Numbers in the margin indicate pagination in the foreign text.

and a single radially parabolic reflector.

Antennae made from radially quadratic reflectors are generally comprised of a feed system, consisting of a feed horn and quadratic reflectors, and a radially parabolic reflector. The elements of the quadratic reflector system of the feed system consist of a radially hyperbolic reflector, a radially eliptical reflector, and a pair of radially parabolic reflectors with parallel radial axes, as shown in Figure 3, all of which are aligned so that their adjacent reflectors share a common focal point.

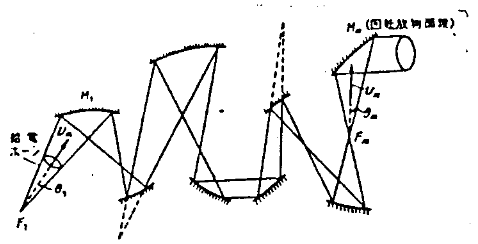
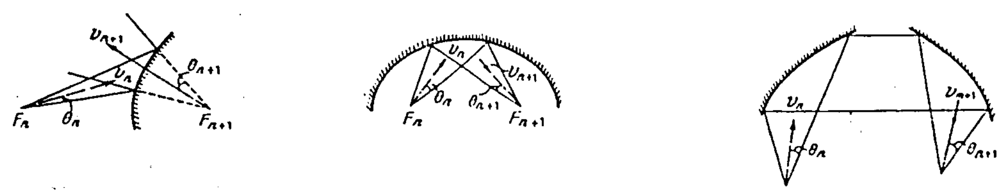


Fig. 2 A radially quadratic reflector system

key
a feed horn
b radially parabolic

These elements possess a characteristic in which the light rays which are radiated along the focal point from one direction of reflector these elements become the reflected light rays which travel along the focal point in another direction, but after the light rays which travel along the cone which forms the vertex of



(a) example of radially hyperbolic reflector (b) example of radially parabolic reflector (c) example of a pair of radially quadratic reflectors

Fig. 3 Elements of a radially quadratic reflector system in the feed system

the focal point of the one direction are reflected, they travel along the cone which forms the vertex of the focal point in their reflected direction. When the unit vector of the along the center of the incidental light ray cone is $\mathbf{v}_n$, and half the vertical angle of the cone is Θ_n, and the respective cones which accompany the reflected light rays are $\mathbf{v}_{n+1}$ and $\Theta_{n=1}$, the following relationships generally exists.

$$\left.\begin{aligned} v_{n+1} &= z_n(A_n \cdot v_n + b_n \cos\theta_n) \\ \cos\theta_{n+1} &= z_n(a_n \cdot v_n + b_n \cos\theta_n) \\ \sin\theta_{n+1} &= z_n \sin\theta_n \end{aligned}\right\} \quad (1)$$

In the above formula, $\mathbf{A}_n$ is a three-line, three-column matrix, $\mathbf{b}_n$ and $\mathbf{a}_n$ are vectors, and z_n and b_n are scalar, all of which are constants decided by the shape and arrangement of each of the reflectors. The following relationships are created in the feed system by again applying the formula (1).

$$\left.\begin{aligned} v_m &= z(A \cdot v_1 + b \cos\theta_1) \\ \cos\theta_m &= z(a \cdot v_1 + b \cos\theta_1) \\ \sin\theta_m &= z \sin\theta_1 \end{aligned}\right\} \quad (2)$$

$\mathbf{A}$, $\mathbf{b}$, $\mathbf{a}$, b, and z are constants which are decided by the geometrical composition of the system.

Light rays which travel along the focal cone of radially parabolic reflectors travel along a cylinder which is parallel to the radial axis of the reflector after being reflected. If an aperture plane is considered in /708 an appropriate position, as shown in Figure 4, a circle is formed at the intersection of the cylinder and the plane. If the foot of a line perpendicular to the aperture plane, drawn from

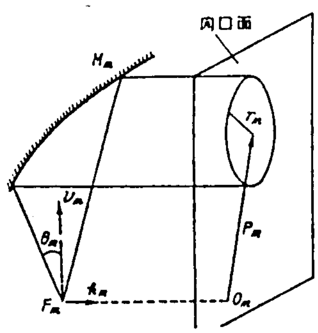


Fig. 4 Radially parabolic reflector

key
a aperture plane

the focal point, and lying in the aperture plane, is O_m, the vector which reaches from $\mathbf{O_m}$ to the center of the above-mentioned circle is $\mathbf{p_m}$, and the radius of that circle is $\mathbf{r_m}$, the following formula becomes true.

$$\left.\begin{aligned} p_m &= 2f_m \cdot \frac{v_m - (v_m \cdot k_m)k_m}{\cos\theta_m - (v_m \cdot k_m)} \\ r_m &= 2f_m \frac{\sin\theta_m}{\cos\theta_m - (v_m \cdot k_m)} \end{aligned}\right\} \qquad (3)$$

f_m is the focal gap of the radially parabolic reflector, and $\mathbf{k_m}$ is the unit vector along the radial axis. If formulae (2) and (3) are substituted, the following results are obtained.

$$\left.\begin{aligned} p_m &= 2f\left\{\frac{v - (v \cdot k_m)k_m}{\cos\theta_1 - (v \cdot k_m)} + d\right\} \\ r_m &= 2f \frac{\sin\theta_1}{\cos\theta_1 - (v \cdot k_m)} \end{aligned}\right\} \qquad (4)$$

wherein,

$$\left.\begin{aligned} f &= \frac{f_m}{b - (b \cdot k_m)} \\ v &= L \cdot v_1 \\ d &= b - (b \cdot k_m)k_m \end{aligned}\right\} \qquad (5)$$

and L is a right-angle matrix drawn from A, b, a, and $\mathbf{k_m}$, and v is the unit vector.

These results show that the radially quadratic reflector system shown in Figure 2 has the same values as a general conical horn-reflector antenna comprised of a conical horn with a bisected angle of θ_n and a radially parabolic reflector with a focal gap of f. Now, it was discovered that the focal point of the radially parabolic reflector at the end of this system is displaced only 2fd from a comparable reflector of an average conical horn-reflector antenna, and that the coordinate system affiliated with the feed horn is subject to the perpendicular exchange shown in the second formula in formula (5).

The equivalent general conical horn-reflector antenna referred to herein is an expansion on the concept of the equivalent parabola [4], commonly known in connection with conventional radially symmetrical Cassegrain antennas. Since the dispersion of illumination intensity fluctuates in actual multi-reflector systems due to diffraction between each of the reflectors, these results can be only be applied as no more than approximations, but they are extremely useful in understanding the operation of complex systems. For example, since the elevation rotations in the antenna shown in Figure 1 are reflected in the fluctuations in the constants of equivalent general conical horn-reflector antennas, their effects on the radiation properties of the antenna can be understood and discussed.

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(received March 10, 1970)

STANDARD TITLE PAGE

1. Report No. NASA TM-88522	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle PROPERTY OF RADIALLY QUADRATIC REFLECTOR SYSTEMS		5. Report Date september 1986
		6. Performing Organization Code
7. Author(s) Mizusawa, M. and Katagi, T.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Jet Propulsion Laboratory 4800 Oak Grove Dr., Pasadena CA 91109		11. Contract or Grant No. n/a
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON , D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of: Japanese Electronics and Communications Society Journal, Vol. 53, No. 1, November 1970, pp. 707-708

16. Abstract

This report shows that when considered in terms of optical-geometry, radially parabolic and radially hyperbolic mirrors used as mirrors for cassegrain and parabolic antennaa posses similar values to common conical horn reflector antennas.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNLIMITED	6	